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In the case of the electrically heated tanks, the glass melt is heated conductively using alternating current by electrodes, i.e. the glass melt is heated directly. The electrodes are introduced into the glass melt either through the tank base or through the side walls of the tank and are surrounded by the glass melt on all sides. In this context, reference should be made to US 4,246,433.

The electrode material used is often molybdenum or platinum. The Mo electrodes have a very strong tendency to be oxidized, and therefore should not generally come into contact with air. Glass melts containing redox elements, such as for example Sb_2O_5 and As_2O_5, can also attack the Mo or Pt electrodes.

Pt electrodes are significantly more resistant to oxidation but can only be used stably for a long time up to temperatures of 1 500°C, or for a short time up to 1 650°C.

Patents GB 644,463 and DE 100 05 821 have disclosed rod electrodes cooled by water alone. However, on account of the maximum current which can be applied per unit area of the electrodes, only a limited amount of power can be supplied using cooled rod electrodes. Heating of a melting unit with strongly cooled walls is only possible to a very restricted extent using an electrode of this type, since it is impossible to introduce higher power densities.

Electrodes with larger surfaces - known as plate electrodes -

are described, inter alia, in patents SU 1016259 or DE 2705618. Electrodes of this type have the advantage that they can be exposed to higher current loads on account of the large electrode surface area.

Claims

1. A method for heating a melt (22) in a melting vessel (3) with cooled walls, the melt (22) being conductively heated, and the current flowing between at least two cooled electrodes (5, 501, 502), wherein the electrodes (5, 501, 502) each replace part of the wall (14, 16) of the melting vessel (3) and the melt-contact surface (51) forms a wall region of the melting vessel.

2. The method as claimed in claim 1, characterized in that at least a region of the melt is heated by the current to a temperature which is above the application limit temperature, in particular above the melting or decomposition temperature of the melt-contact material of at least one of the electrodes (5, 501, 502).

3. The method as claimed in claim 1 or 2, wherein the electrodes (5, 501, 502) are cooled in a manner which can be set and/or controlled separately.

4. The method as claimed in claim 1, 2 or 3, wherein the electrodes (5, 501, 502) are inserted into cutouts in cooled walls of the melting vessel.

5. The method as claimed in one of claims 1 to 4, wherein the cooling is effected by passing at least one cooling fluid, in particular air and/or water, through the electrodes (5, 501, 502).

6. The method as claimed in claim 5, wherein the cooling is effected by passing through a gaseous cooling fluid, in particular air, by means of a low-pressure blower.

7. The method as claimed in claim 6, wherein the coolant is passed through the electrodes (5, 501, 502) with a pressure difference of less than 1 000 mbar, preferably less than 500 mbar, particularly preferably less than 150 mbar.

8. The method as claimed in one of claims 1 to 7, wherein the melt is additionally heated by the introduction of radiant energy, in particular by infrared radiation.

9. The method as claimed in one of claims 1 to 8, wherein the melt (22) is heated by alternating current, preferably with an alternating current frequency in a range from 50 Hz to 50 kHz, particularly preferably with an alternating current frequency in a range from 2 kHz to 10 kHz.

10. The method as claimed in one of claims 1 to 9, wherein the temperature of the walls (14, 16) of the melting vessel (3) and of the electrodes (5, 501, 502) is kept below a temperature at which high levels of corrosion occur.

11. The method as claimed in one of claims 1 to 10, wherein the temperature of the melt (22) is kept at least in a range above 1 600°C, preferably above 1 700°C.

12. The method as claimed in one of claims 1 to 11, wherein the temperature of the melt-contact surface of the at least two electrodes (5, 501, 502) is kept below 1 650°C, preferably below 1 500°C.

13. The method as claimed in claims 1 to 12, wherein the temperature difference between the melt (22) in the edge region of the melting vessel (3) and the melt (22) in the central region of the melting unit amounts to more than 150°K, preferably more than 250°K.

14. The method as claimed in one of claims 1 to 13, wherein the conductivity of the melt (22) at the melting temperature has an electrical conductivity in a range from 10^{-3} to 10^{2} Ω^{-1}* cm^{-1}, preferably in a range from 10^{-2} to 10^{1} Ω^{-1}* cm^{-1}.

15. The method as claimed in one of claims 1 to 14, wherein for a given heating power the current which emerges from the electrodes (5, 501, 502) into the melt (22) does not exceed a current density of 5 A/cm^2 at any point.

16. The method as claimed in one of claims 1 to 15, wherein melting material is supplied and discharged continuously.

17. The method as claimed in claim 16, wherein the melting material is supplied in molten form via an inlet (9) and is discharged in molten form via an outlet (10).

18. The method as claimed in claim 16 or 17, wherein the heating current flows between the electrodes substantially along the main direction of flow of the melt (22) or perpendicular with respect thereto.

19. The method as claimed in claim 18, in which a temperature difference of more than 150°K, preferably of more than 250°K, is set between the melt-contact surface of the electrodes and a region of the melt (22) located substantially centrally between the electrodes.

20. The method as claimed in one of claims 17 to 19, wherein inlet (9) and outlet (10) supply and discharge the melting material in the region of the melt bath surface (24).

21. The method as claimed in one of claims 1 to 20, wherein

at least one electrode (5, 501, 502) is heated at least from time to time.

22. The method as claimed in claim 21, wherein the heating of the electrode is effected by transverse application of current to the melt-contact material.

23. The method as claimed in one of claims 1 to 22, which includes a starting operation in which a melt path of sufficient electrical conductivity is provided between electrodes in the melting vessel.

24. The method as claimed in claim 23, wherein the electrodes and/or parts of the wall, during the starting operation, are heated by a heating apparatus to a sufficient temperature for their temperature to be above the dew point of the furnace upper atmosphere.

25. The method as claimed in claim 23 or 24, wherein to melt down the melting material starting electrodes are introduced into the melting vessel and a current is passed through the melting material via the starting electrodes.

26. The method as claimed in claim 25, wherein the starting electrodes are moved away from one another during the starting operation.

27. The method as claimed in one of claims 23 to 26, which incorporates melt conversion from a melt with a higher electrical conductivity to a melt with a lower electrical conductivity.

28. The method as claimed in one of claims 23 to 27, wherein the electrodes are pushed together before the starting operation and are pulled apart during the starting operation.

29. The method as claimed in one of claims 23 to 28, wherein radiant energy, in particular infrared radiation, is fed to the melting material in order for the latter to be melted down during the starting operation.

30. An apparatus (1) for the heating of melts, in particular for the high-temperature refining of melts, comprising:

- a melting vessel (3) with cooled walls (14, 16) for receiving melting material, and
- at least two electrodes (5, 501, 502) for conductively heating the melt (22),

wherein the electrodes (5, 501, 502) each replace part of the wall (14, 16) of the melting vessel (3) and the melt-contact surface (51) forms a wall region of the melting vessel.

31. The apparatus as claimed in claim 30, wherein the electrodes (5, 501, 502) are inserted into cutouts in the wall (14, 16) of the melting vessel (3).

32. The apparatus as claimed in claim 30 or 31, wherein the electrode surface area replaces more than 1%, preferably more than 10% and particularly preferably more than 15% of the wall surface area of the melting vessel.

33. The apparatus as claimed in claim 30, 31 or 32, which includes at least one device for cooling the electrodes (5, 501, 502), in particular for cooling the melt-contact material of the electrodes (5, 501, 502).

34. The apparatus as claimed in claim 33, wherein the at least one device for cooling the electrodes (5, 501, 502) comprises a fluid-conveying device.

35. The apparatus as claimed in claim 34, wherein the fluid-conveying device comprises a low-pressure blower, in particular a low-pressure blower which builds up a pressure difference of less than 1 000 mbar, preferably less than 500 mbar, particularly preferably less than 150 mbar.

36. The apparatus as claimed in one of claims 30 to 35, wherein the electrodes (5, 501, 502) have cooling-fluid passages, in particular wherein the cooling-fluid passages are of dimensions such that a sufficient flow of cooling fluid is achieved even at a cooling fluid pressure difference of 150 mbar or less.

37. The apparatus as claimed in one of claims 30 to 36, wherein the device for cooling the electrodes (5, 501, 502) comprises at least two cooling circuits, preferably for two different cooling media, particularly preferably for air and/or an aerosol and/or water.

38. The apparatus as claimed in claim 36 or 37, which includes a device for controlling the cooling power of the electrodes (5, 501, 502).

39. The apparatus as claimed in one of claims 33 to 38, which includes a further device for cooling that region of the wall (14, 16) of the melting vessel (3) which is not formed by the electrodes.

40. The apparatus as claimed in one of claims 30 to 39, wherein the melting vessel (3) comprises skull walls and/or ceramic walls.

41. The apparatus as claimed in claim 40, in which the melting vessel (3) comprises skull walls, wherein the skull walls, which preferably comprise cooled metallic tubes, are

lined with a material of poor electrical conductivity, preferably in the form of ceramic plates or slip, in particular SiO_2 slip, on the side facing the melt (22).

42. The apparatus as claimed in one of claims 30 to 41, wherein the electrodes (5, 501, 502) are arranged electrically insulated, in particular electrically insulated with respect to the wall (14, 16) of the melting vessel (3).

43. The apparatus as claimed in one of claims 30 to 42, which includes a device for generating alternating current (18, 20), preferably with an alternating current frequency in a range from 50 Hz to 50 kHz, particularly preferably with an alternating current frequency in a range from 2 kHz to 10 kHz.

44. The apparatus as claimed in one of claims 30 to 43, wherein the electrodes (5, 501, 502) comprise plate and/or button and/or rod electrodes.

45. The apparatus as claimed in one of claims 30 to 44, wherein the electrodes (5, 501, 502) include a melt-contact material which comprises electrically conductive ceramic, such as for example SnO_2 ceramic and/or refractory metals, in particular high-melting metals, in particular tungsten, molybdenum, tantalum, osmium, hafnium or alloys thereof, and/or platinum metals, in particular platinum, iridium, rhodium or alloys thereof.

46. The apparatus as claimed in one of claims 30 to 45, wherein the electrodes (5, 501, 502) include a melt-contact material, which comprises a fine-grain-stabilized material, in particular a high-strength platinum material.

47. The apparatus as claimed in one of claims 30 to 46, wherein the electrodes (5, 501, 502) and/or the walls (14, 16) of the melting vessel (3) are chemically resistant with respect to the melt (22).

48. The apparatus as claimed in one of claims 30 to 47, wherein at least one of the electrodes (5, 501, 502) has at least two electrode segments.

49. The apparatus as claimed in one of claims 30 to 48, wherein the electrodes (5, 501, 502) are preferably arranged in the lower part of the melting vessel (3), in such a way that they are positioned opposite one another in the direction of flow of the melt (22) or perpendicular with respect thereto.

50. The apparatus as claimed in one of claims 30 to 49, wherein the electrodes (5, 501, 502) are exchangeably secured to the apparatus.

51. The apparatus as claimed in one of claims 30 to 50, wherein the electrodes (5, 501, 502) are arranged in the lower part of the melting vessel (3), preferably below the melt bath surface (24) in the region of the lower two thirds of the height of the melting vessel (3).

52. The apparatus as claimed in one of claims 30 to 51, which includes a plurality of electrode pairs and/or a plurality of pairs of electrode segments.

53. The apparatus as claimed in one of claims 30 to 52, wherein the melt-contact surfaces (51) of the electrodes (5, 501, 502) are arranged obliquely with respect to one another.

54. The apparatus as claimed in one of claims 30 to 53, wherein, as seen in the direction of the main direction of flow of the melt (22), the electrodes (5, 501, 502) are preferably arranged in such a way in the lower part of the melting vessel (3) that they are positioned opposite one another in the direction of flow of the melt (22).

55. The apparatus as claimed in one of claims 30 to 54, wherein the melting vessel (3) has a square, rectangular, polygonal, oval or circular basic contour.

56. The apparatus as claimed in one of claims 30 to 55, wherein at least one of the electrodes (5, 501, 502) forms a region of the wall (14, 16) of the melt vessel (3) which is planar or annular or in the form of a segment of a ring.

57. The apparatus as claimed in one of claims 30 to 56, which includes a bridge that is preferably arranged in such a way that it is immersed into the melt (22) from above through the melt bath surface (24).

58. The apparatus as claimed in one of claims 30 to 57, which includes a device for additional heating.

59. The apparatus as claimed in claim 58, wherein the device for additional heating comprises at least one fossil burner (28, 29) and/or at least one plasma torch and/or at least one resistance heating element and/or at least one infrared radiator.

60. The apparatus as claimed in one of claims 30 to 59, which includes at least one outlet (15) for the melt (22) at the base of the melting vessel (3).

61. The apparatus as claimed in one of claims 30 to 60, which includes at least one blowing nozzle (32) preferably arranged at the base (14) of the melting vessel (3).

62. The apparatus as claimed in one of claims 30 to 61, wherein at least one of the electrodes (5, 501, 502) comprises a heating apparatus.

63. The apparatus as claimed in claim 62, wherein the heating apparatus comprises an ohmic heating device.

64. The apparatus as claimed in claim 62 or 63, wherein the heating apparatus comprises a current source (33) which is connected to the melt-contact material or a conductive material located beneath it.

65. The apparatus as claimed in one of claims 62 to 64, wherein the heating apparatus comprises an apparatus for heating a cooling fluid.

66. The apparatus as claimed in claim 65, wherein the heating apparatus comprises an electrical and/or fossil heater and/or a waste heat heater.

67. The apparatus as claimed in one of claims 30 to 66, wherein the electrodes are arranged displaceably.

68. An apparatus (1) for heating melts, having a melting, conditioning or refining vessel (3) for receiving melting material, in particular as claimed in one of claims 30 to 67, wherein the melting, conditioning or refining vessel (3) has a surface which reflects infrared radiation.

69. The apparatus (1) as claimed in claim 68, wherein the surface which reflects infrared radiation is polished.

70. The apparatus (1) as claimed in claim 68 or 69, wherein the surface which reflects infrared radiation comprises a coating that reflects infrared radiation, in particular a gold, platinum, nickel, chromium or rhodium coating.

71. The apparatus (1) as claimed in one of claims 68 to 70, wherein the surface which reflects infrared radiation comprises the surface of the melt-contact material of at least two electrodes (5, 501, 502) for conductively heating the melt (22), these electrodes (5, 501, 502) replacing parts of the wall (14, 16) of the melting, conditioning or refining vessel (3).